Bighorn Sheep Habitat Assessment of the Greater Bighorn Canyon National Recreation Area

epared cooperatively by: National Park Service, Rocky Mountain Region
ational Biological Service, Midcontinent Ecological Science Center

996

Copies of this report can be obtained by writing to the National Biological Service, Mountain Ecosystems Section, Midcontinent Ecological Science Center, 4512 McMurry Ave., Fort Collins, Colorado 80525-3400.

Bighorn Sheep Habitat Assessment of the Greater Bighorn Canyon National Recreation Area

The Biological Panel

Report preparation:

Michelle Gudorf[1] GIS analysis, panel organization
Patricia Sweanor[2] synthesis, writing
Francis Singer[2] project initiation, coordination

[1] National Park Service, Rocky Mtn. Region, 12795 W. Alameda Pkwy., Lakewood, CO 80228
[2] National Biological Service, MESC, 4512 McMurry Ave., Fort Collins, CO 80525

Bighorn sheep and resource consultation:

Ann Blankinship	Bighorn National Forest, P.O. Box 831, Greybull, WY 82426
Vern Bleich	California Department of Fish and Game, 407 W. Line St. Bishop, CA 93514
Tom Easterly	Wyoming Game & Fish, 132 N 5th, Greybull, WY 82426
John Emmerich	Wyoming Game &Fish, 2820 State Hwy 120, Cody, WY 82414
Charles Eustace	Montana Fish, Wildlife & Parks, 2300 Lake Elmo Dr., Billings, MT 59105
Lynn Irby	Montana State Univ., Bozeman, MT 59717
David Jaynes	BLM, 810 E. Main, Billings, MT 59105
Bert Jellison	Wyoming Game & Fish, P.O. Box 6249, Sheridan WY 82801
Robert Kissell	Montana State Univ., Bozeman, MT 55717
Jack Lindsay	Bighorn Canyon NRA, 20 Hwy 14A, Lovell, WY 82431
Jay Parks	BLM, 810 E. Main, Billings, MT 59105
Terry Peters	Bighorn Canyon NRA, 20 Hwy 14A, Lovell, WY 82431
Kim Reid	Custer National Forest, HC 49, Box 3420, Red Lodge, MT 59068
Shawn Stewart	Montana Fish, Wildlife & Parks, Box 581, RedLodge, MT 59068
Tom Voss	BLM, 810 E. Main, Billings, MT 59105

Acknowledgments:

Major funding for this project was provided by the National Park Service Resource Preservation Program (NRPP), Washington office. Significant cooperative and cost share funding was contributed by the Bureau of Land Management, the U.S. Forest Service, states of Utah, South Dakota and Colorado and the Foundation for North American Wild Sheep. We thank the Bureau of Indian Affairs, the Bureau of Land Management, and the U.S. Forest Service in Wyoming and Montana for providing us with data for this project.

Table of Contents

INTRODUCTION

The Rocky Mountain Region Bighorn Sheep Restoration Program

Wide-spread population declines and local extinctions during the past century eliminated bighorn sheep (*Ovis canadensis*) from most of their historical range in the western United States (Buechner 1960). Reductions in the numbers and distribution of bighorn sheep have been attributed to human activities and land management practices that alter bighorn sheep habitat (Bear and Jones 1973, Wishart 1978, Wakelyn 1987).

A fundamental policy of the National Park Service is to perpetuate wildlife in natural ecosystems (USDI 1988). The National Park Service strives to restore native animal species to areas where they have been extirpated if adequate habitat to support the species exists or can be restored, and if, once a population is reestablished, it can be self-perpetuating.

Past reintroduction efforts to restore bighorn sheep to their former ranges have had variable success (Rowland and Schmidt 1981, Bailey 1990). A variety of factors, such as poor range conditions, competition with other ungulates, infection with domestic livestock diseases, unsuitable juxtaposition of habitat components, inadequate quantities of critical seasonal ranges or excessive human disturbance have caused reintroductions to fail (Rowland and Schmidt 1981, Smith *et al.* 1988).

In 1991, the Rocky Mountain Region of the National Park Service, initiated a bighorn sheep restoration program. The purpose of the program is to restore bighorn sheep populations through interagency cooperation, to historical ranges in national parks and adjacent lands that have suitable habitat to support viable populations.

Statement of the Problem and Study Objective

Bighorn sheep are native to the Bighorn Mountains, Bighorn Canyon, and Pryor Mountains of Wyoming and Montana. However, indigenous bighorn sheep have been extirpated from the region. Beginning in the 1930's, bighorn sheep were translocated into these areas in attempts to establish viable, self-sustaining populations. Some translocations were successful, others failed, and some resulted in unexpected dispersal.

Our objective is to evaluate habitat in the greater Bighorn Canyon National Recreation Area to aid in the establishment and management of viable populations of bighorn sheep. We identify habitat factors that limit bighorn sheep in the region, evaluate and identify unoccupied habitat, and propose habitat management strategies, studies and translocations of bighorn sheep when appropriate.

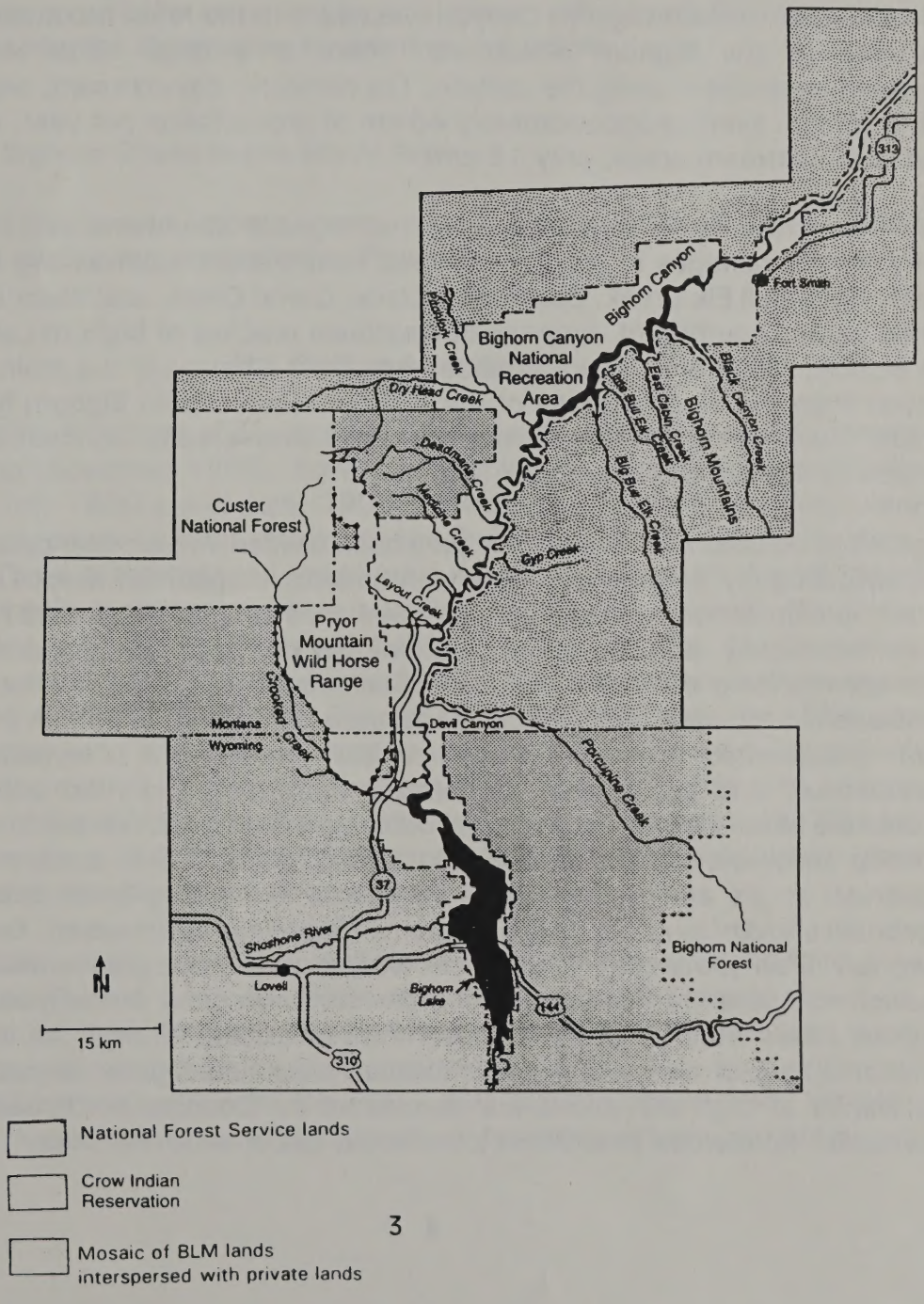
THE STUDY AREA

Vegetation, Climate, Land Use

The 3418 km^2 study area is on the Wyoming-Montana border and encompasses Bighorn Canyon National Recreation Area and the Pryor Mountain Wild Horse Range. Portions of the Custer National Forest, Bighorn National Forest and Crow Indian Reservation, as well as Bureau of Land Management and private lands are included in the study area (Fig. 1). The Bighorn River Canyon dissects the study area, with the Pryor Mountains to the west, and the Bighorn Mountains to the east.

The Pryor Mountains are small, isolated mountains containing a maze of canyons, limestone caves and steep-sided ridges. The slopes of the mountains are heavily forested; however, alpine-like meadows, dryland flats and sparsely-vegetated canyons are interspersed in the forested areas. Elevations in the mountains vary from approximately 900 to 2500 m. Precipitation varies with elevation, and ranges from 18 to 50 cm per year.

Figure 1. The study area for bighorn sheep habitat assessment, in north central Wyoming and southeastern Montana, encompasses Bighorn Canyon National Recreation Area and the Pryor Mountain Wild Horse Range. National Forest Service, Bureau of Land Management and private lands are interspersed through the study area.



The Bighorn River carved the narrow, approximately 200 m deep, Bighorn Canyon. Cave-forming limestone cliffs and talus slopes rise from the water's edge, creating an abrupt barrier in the shrublands and grasslands that surround the canyon. The lowest point of the canyon floor is approximately 1100 m and the highest canyon wall is over 1700 m. In 1967, the Bighorn River was dammed near Fort Smith, Montana, creating the 100-km-long Bighorn Lake. Side canyons connect Bighorn Canyon westward to the Pryor Mountains, and eastward to the Bighorn Mountains. There is a large north to south precipitation gradient along the canyon. The northern, downstream, segments of the canyon average approximately 45 cm of precipitation per year, and the southern, upstream areas, only 15 cm.

Only the northwestern-most ridges of the Bighorn Mountains occur in the study area. Drainages in the Crow Indian Reservation, such as Big Bull Elk Creek, Little Bull Elk Creek, East Cabin Creek, Corral Creek, and Black Canyon Creek, extend southward, from the downstream reaches of Bighorn Lake, into the Bighorn Mountains. Further upstream, Devil Canyon is the main feeder canyon from the western ridge of the Bighorn Mountains in Bighorn National Forest. The creeks, and the canyon corridors they create, connect Bighorn Canyon to the Bighorn Mountains (Fig. 1).

Vegetation communities in the area have been divided into 6 major categories: juniper/mahogany shrublands, desert shrublands, sagebrush steppe, grasslands, riparian zones, and coniferous woodlands (Knight *et al.* 1987). The juniper/mahogany shrublands are dominated by Utah juniper *(Juniperus osteosperma)* and curlleaf mahogany *(Cercocarpus ledifolius).* The desert shrubland is a mixture of sagebrush *(Artemisia tridentata)*, saltbrush (*Atriplex spp.*), greasewood *(Sarcobatus vermiculatus)*, rabbitbrush (*Chrysothamnus viscidiflorus*), and snakeweed (*Gutierrezia sarothrae*). Common understory grasses are bluebunch wheatgrass (*Pseudoroegnari spicata)*, Fendler three awn (*Aristida fendleriana*), and needle and thread grass (*Stipa comata*). The sagebrush zones are predominantly vegetated in big sagebrush and black sagebrush (*Artemisia nova*). Sideoats grama (*Bouteloua curitendula*), Kentucky bluegrass (*Poa pratensis*), bluebunch wheatgrass, blue grama (*Bouteloua gracilis*), needle and thread grass, and diverse forbs grow in the grasslands. Riparian zones support cottonwoods, (*Populus spp.*), as well as invading tamarisk (*Tamirix chinensis*) and Russian olive (*Elaeagnus angustifolia*). Woodlands at high elevations are dominated by Douglas fir (*Psuedotsuga menziesii*). Ponderosa pine (*Pinus ponderosa*) occur on lower slopes.

The study area has a climate characterized by long, cold winters and hot, dry summers. However the area is geographically diverse and weather patterns are locally variable. Semi-arid, near desert-like conditions near Bighorn Canyon are in contrast to the sub-alpine zones of the higher elevations.

The predominant land use in the past century has been cattle ranching. Tourism is economically important to local communities, and Bighorn Lake is a popular recreation destination for boating and fishing.

History of Bighorn Sheep in the Study Area

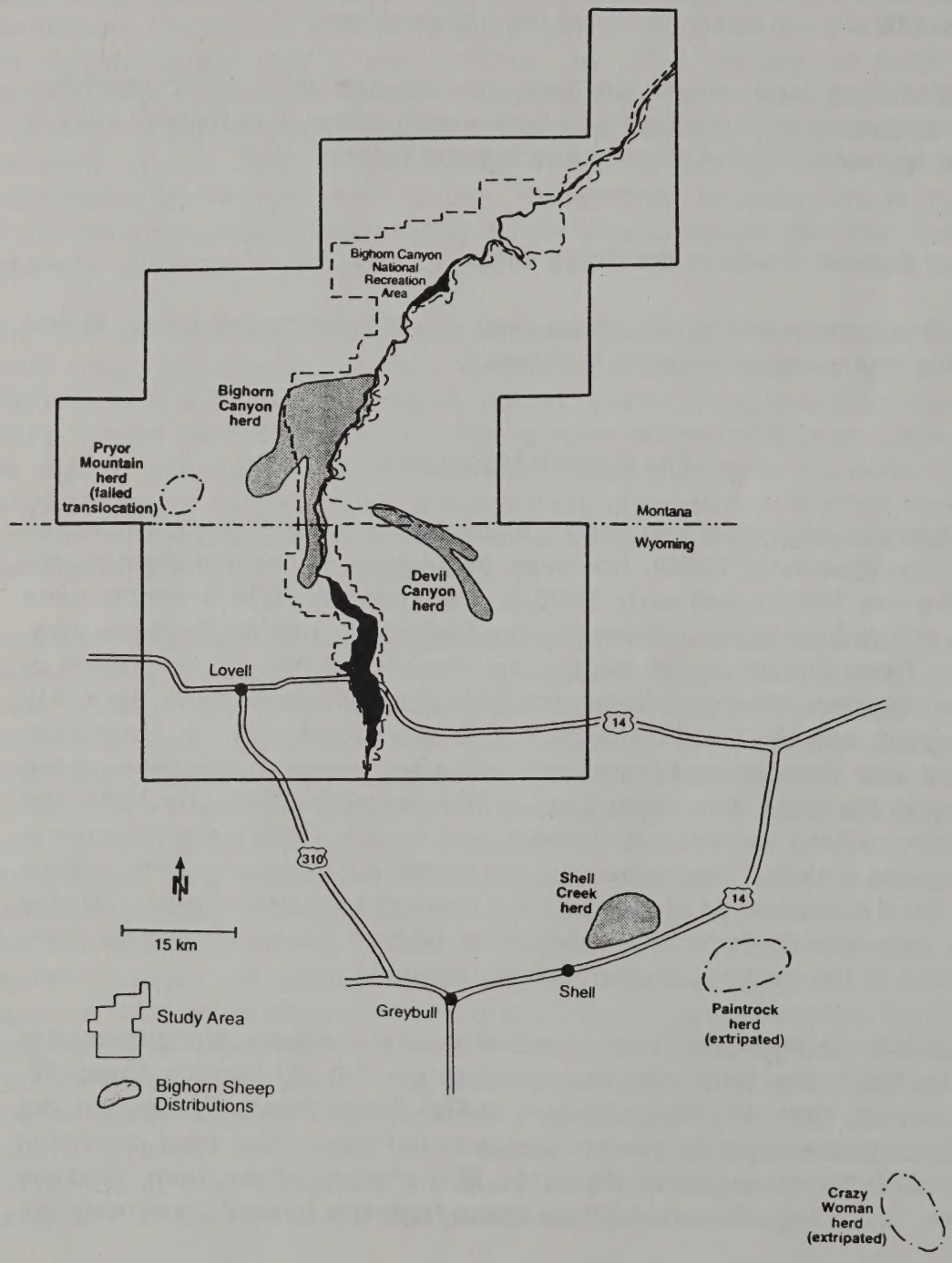
Current distributions of bighorn sheep, and recently extirpated herds, in and around the study area are shown in Figure 2.

The Bighorn Mountains

Rocky Mountain bighorn sheep occurred historically in the Bighorn Mountains of Wyoming (Buechner 1960), however, populations decreased dramatically during the late 1800's and early 1900's. Beginning in 1934 attempts were made to reintroduce bighorn sheep into the Bighorn Mountains (Easterly, pers. comm.). Three bighorn sheep herds were established through the efforts of the Wyoming Department of Game and Fish: the Paint Rock herd, the Crazy Woman herd, and the Devil Canyon herd (Gibson 1984, Fig. 2). During the 1950's, it was thought that there were still a few indigenous bighorn sheep remaining in the Paint Rock area. Despite translocation efforts, by 1984, the Crazy Woman herd had been extirpated, and by the 1990's the Paint Rock herd was also extinct. The herds were not monitored during this time and the reasons for the extirpation of these herds were not fully understood. Disease and the presence of domestic livestock on bighorn sheep range may have contributed to the declines (Easterly, pers. comm.).

The Devil Canyon herd continues to persist in small numbers, along Porcupine Creek. In 1985, the herd was estimated to contain 40 bighorn sheep (V. Stelter, unpubl. data, Wyoming Game and Fish Department). The herd is not currently monitored and its present status is unknown. This herd originated from a 1973 translocation of 39 (31F, 8M) bighorn sheep from Whiskey Mountain, Wyoming. Several bighorn sheep from this release were reported

Fig. 2. Current distributions of bighorn sheep and recently extirpated herds in and around the study area.



to have crossed Bighorn Canyon and Bighorn Lake into the National Recreation Area and helped establish the Bighorn Canyon herd (Bighorn Canyon NRA 1985).

The Shell Creek herd was established in 1992 with the release of 48 bighorn sheep: 26 (13F, 13M) from the Whiskey Mountain herd and 22 (18F, 9M) from a herd near Challis, Idaho. In 1993 and 1994, bighorn sheep were again translocated from Whiskey Mountain into Shell Creek, 28 (19F, 9M) and 35 (26F, 9M), respectively. However, mortality has been high and recruitment, low. The Shell Creek herd is currently estimated to consist of less than 50 bighorn sheep (Easterly pers. comm.). The most commonly recorded cause of mortality in this herd has been pneumonia, but predation has also been reported (Easterly, pers comm.). Domestic sheep, a potential source for pneumonia infections (Jessup 1981), occur 8 km to the south and 15 km to the north of this herd. Dispersing bighorn sheep from the Shell Creek herd have moved north to Horse Creek, 30 km from the Devil Canyon herd.

The Pryor Mountains

In 1971 and 1974 the Montana Department of Fish, Wildlife and Parks translocated 77 bighorn sheep from the Sun River, Idaho herd in into Bear Canyon in the Pryor Mountains, west of Bighorn Canyon National Recreation Area (Fig. 2). Most of the translocated bighorn sheep dispersed from the release site. Several bighorn sheep that dispersed into the Crow Indian Reservation were killed. In 1976, only 6 bighorn sheep were counted near the release site and 6 more were sighted in neighboring Dry Head Creek (Sloan 1995).

Bighorn Canyon

The herd in Bighorn Canyon National Recreation Area (Fig. 2) is believed to have originated from bighorn sheep dispersing from the translocations in Bear Canyon in the Pryor Mountains, as well as from Devil Canyon (Coates and Schemnitz 1988, 1989, Fitzsimmons 1992, Sloan 1995). Coates and Schemnitz (1989) estimated that the herd in Bighorn Canyon National Recreation Area increased from 40 individuals in 1985 to 99, in 1989. Eighty-five bighorn sheep were counted during a census in spring, 1994. Using

Chapman's population estimator (Chapman 1951), Irby *et al.* (1994) estimated that there were 158 $\pm$ 41 bighorn sheep in the population. The distribution of the herd in Bighorn Canyon NRA also increased during the 1980's and 90's (Coates and Schemnitz 1989, Irby *et al.* 1994). Adoption of a new lambing range has highlighted the distribution expansion. Most lambing occurs on the limestone ledges and talus slopes of Bighorn Canyon; however, in 1994, ewes lambed in the Crooked Creek drainage, 10 km west of the primary lambing area (Irby *et al.* 1994).

METHODS

The Habitat Evaluation Procedure

Habitat parameters considered critical for Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) were defined by Smith *et al.* (1991, Table 1). These parameters were derived from the literature, applied to a population of bighorn sheep on Bear Mountain, Utah, and used to develop a model for evaluating bighorn sheep habitat (Smith *et al.* 1991). The model was tested and refined (Johnson and Swift 1995) by evaluating habitat parameters in areas with successful versus unsuccessful bighorn sheep translocations in Colorado.

The model identifies regions of habitat adequate to support a minimum viable population of bighorn sheep. A population of 100 - 125 individuals has been proposed as the number of bighorn necessary for short-term persistence through several decades (Sands 1976, Van Dyke *et al.* 1983, Berger 1990). In this study, a minimum viable population was defined as 125 bighorn. Metapopulations were defined as collective subpopulations with limited gene flow (Schwartz *et al.* 1986, Bleich *et al.* 1990).

The habitat model incorporates a process of elimination, where land area is systematically removed from consideration if it does not meet specific habitat constraints (Table 1). Remaining land areas may be considered suitable bighorn sheep habitat. The model also helps identify areas that do not presently meet criteria necessary to be considered suitable habitat but that could be managed or manipulated to become suitable. Patches of habitat deemed suitable must be of sufficient size to sustain a viable population or must occur in proximity, such that the combined area would support a viable metapopulation.

Habitat Requirement	Effect on Land Area Available
geophysical/biological parameters	
Escape Terrain (ET) and Buffer (BT)	Include land areas with slope > 27° , < 85° (i.e. escape terrain), land areas within 300m of escape terrain and land areas, $\leq$ 1000m wide, that are bounded on $\geq$ 2 sides by escape terrain
Horizontal Visibility (HV)	remove areas with visibility < 55%, as defined by the mean percent of squares visible on a m^2 target, divided into 36 equal squares, 14 m from an observer viewing N,E,W,S from a height of 90 cm along a 10 pt, 280 m transect
Water Sources (WS)	remove land areas > 3.2 km from water sources
Natural Barriers (NB)	remove land areas that can not be accessed due to natural barriers: Rivers > 2000 cfs, areas with visibility < 30%, that are 100 m wide, cliffs with > 85° slope
land management constraints	
Human-use Areas (HU)	remove land areas covered by human development
Manmade Barriers (MB)	remove land areas that can not be accessed due to manmade barriers: major highways, wildlife-proof fencing, aqueducts, major canals
Domestic Livestock (DL)	identify land areas within 16 km of domestic sheep husbandry

Table 1. Criteria used in the GIS analysis for determination of suitable bighorn sheep habitat. Escape terrain and buffer (areas proximate to escape terrain) are the primary determinants of bighorn sheep habitat. Other variables limit habitat as in the equation: ET + BT - HV - WS - NB - HU - MB - DL = land area suitable for bighorn sheep, without further management, contingent on constraints not addressed by the GIS (e.g., forage production, predation, nearby bighorn sheep populations or concentrations of other ungulates). The land area available to bighorn sheep is further evaluated for its suitability as seasonal ranges (Table 2).

Data Collection and GIS Interpretation

Values for bighorn sheep habitat parameters were obtained from field observations, historical records, U.S. Geological Survey (USGS) digital elevation models (DEMs), USGS park maps, USGS digital line-graph data (DLG), USGS topographical maps, U.S. Forest Service aerial photos, Bureau of Indian Affairs (BIA) digital data, and Bureau of Land Management (BLM) surface management maps (Table 2). These values were used to identify regions of the study area meeting specific habitat criteria. The geophysical, biological and land-management habitat variables in the Smith *et al.* (1991) model were mapped according to a Geographic Information System (GIS) analysis. This allowed us to integrate and overlay habitat parameters for comparative interpretations of habitat quantity and quality (Burrough 1986). Habitat data were digitized and entered into a computer-based mapping program, called Geographic Resource Analysis and Support System (GRASS). This converts digitized data into a spatial form via grid or pixel cells. The thematic maps produced by GRASS for individual habitat parameters were composed of multitudes of pixel cells delineating areas that met specific habitat criteria. These thematic maps were then overlaid for analysis of areas that met composite habitat requirements of bighorn sheep. GIS was used to delineate areas of winter, lambing and summer ranges. GIS also aided in identifying constraints limiting bighorn sheep habitat. Some constraints may be manageable, and identifying them delineates alternatives for increasing or improving bighorn sheep habitat.

Additional non-GIS considerations pertaining to habitat suitability are forage type and biomass, predation, interagency plans for adjacent regions, wild ungulate concentrations, and nearby bighorn sheep populations.

Parameter Value	Source	Scale
Escape Terrain (slope) and Buffer	USGS Digital Elevation Models (DEMs)	1: 24,000
Horizontal Visibility (vegetation type)	NPS vegetation map, field check of vegetation communities	1: 24,000
Water Sources	USGS Digital Line Graph (DLG) data, USFS aerial photos, Digital information supplied by BLM, BIA and NPS	1:100,000 1: 24,000
Natural Barriers	USGS topographical maps field surveys	1: 24,000
Aspect	USGS DEMs	1: 24,000
Snowpack	not available	-
Human-use Areas	USFS aerial photos USGS topographical maps USGS Land use/Land cover maps BIA digital land use data	1: 24,000 1: 24,000 1:250,000 1: 24,000
Manmade Barriers	USGS Digital Line Graph (DLG) data USFS aerial photos NPS digital data	1: 24 ,000 1: 24,000
Livestock Grazing	USFS allotment data on aerial photos BLM allotment data on BLM District map BIA digital allotment data	1: 24,000 1:100,000 1: 24,000

Table 2. Sources of the bighorn sheep habitat parameter values used in the Geographic Information System (GIS) analysis.

Definition of Bighorn Sheep Habitat Parameters

Habitat Requirements

Geophysical, biological and human management constraints on bighorn sheep habitat were identified in the habitat model (Table 1). Geophysical and biological habitat parameters include escape terrain, horizontal visibility, water sources, natural barriers, aspect and snow pack. Land management parameters are human activities, constructed barriers and livestock grazing.

Escape terrain, defined as slopes 27° - 85°, provide protection from predators and disturbances, and it is a critical habitat feature for bighorn sheep (Honess and Frost 1942, Buechner 1960, Cooperrider 1969, Ferrier and Bradley 1970, Geist 1971, Holl and Bleich 1983, Wilson *et al.* 1980, Van Dyke *et al.* 1983). Buffer areas within 300 m of escape terrain, or within 1000 m, if bordered on more than two sides, were considered to be close enough to escape terrain for bighorn sheep to be able to seek refuge there during disturbances.

Horizontal visibility is a value used to express the openness of the habitat. Bighorn sheep are better able to detect predators and other disturbances, as well as maintain contact with members of their herd, in areas with good visibility (Buechner 1960, Risenhoover 1981, Wakelyn 1984, Cook 1990). In this study, horizontal visibility was defined as the percentage of a bighorn's lateral view that was not obscured by vegetation. Horizontal visibility > 55% was considered adequate (Johnson and Swift 1995).

Water sources for bighorn sheep should be perennial and within 3.2 km of escape terrain and buffered areas (Table 1, McQuivey 1978, Smith *et al.* 1991). However, in non-drought years bighorn sheep are probably not dependent on perennial sources and will range greater than 3.2 km from these sources.

Natural barriers, manmade barriers and human use areas may restrict bighorn sheep movements. These features were identified and evaluated on a case-by-case basis for determination of their hindrance to bighorn sheep occupancy of an area or movement through an area.

Domestic livestock, especially sheep, or feral species in the *Ovis* genus, can harbor diseases that may infect bighorn sheep. Disease transmissions from domestic sheep have caused catastrophic die-offs of bighorn sheep (Jessup 1981, Goodson 1982, Capurro 1988, Coggins 1988). However, Symonds and Singer (in prep.) found that separations of > 10 miles (16 km) between domestic sheep and bighorns reduced the probability of disease transmission. If domestic sheep occur less than 16 km from potential bighorn sheep habitat, translocations of bighorn sheep into that habitat can be considered to be at risk for disease.

Seasonal Range Requirements

Bighorn sheep have varying habitat needs during different periods of the year (Table 3). During summer, bighorn sheep, primarily use grassy slopes near escape terrain. Ewes with lambs require contiguous escape terrain because of their greater vulnerability to predation and other disturbances. Only areas of lambing habitat with greater than 2 ha of escape terrain were considered suitable lambing areas in the model application. Thermal cover is especially important for young lambs born in the spring when weather is unpredictable. Therefore, only slopes, 27° - 85°, that are not north-facing were considered suitable lambing habitats. In addition, lactating ewes require a continuous source of water, and water should occur within 1 km of lambing areas.

In the winter, snow pack greater than 25 cm hinders movement and forage accessibility for bighorn sheep (McCann 1956, Tilton and Willard 1982, Johnson 1983, Smith and Flinders 1991). Therefore, only south-facing slopes or wind swept ridges with snow accumulation < 25 cm should be considered suitable bighorn sheep winter ranges.

Focus Areas

The study area was divided into 4 focus areas (Fig. 3). The focus areas were delineated by natural separations in suitable habitat.

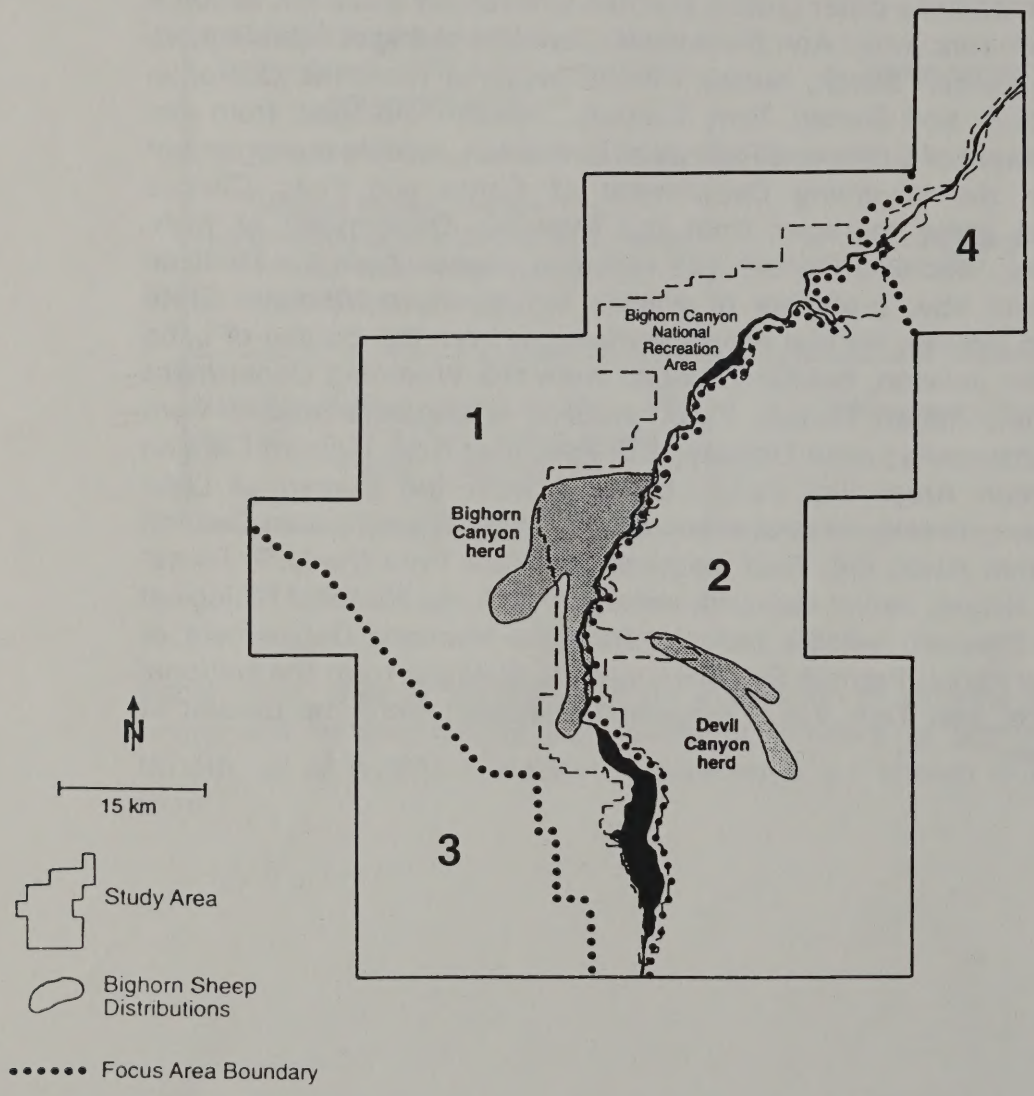
Habitat Requirement Total habitat *minus* exclusionary criteria	Seasonal Range
x - y	= z
Suitable habitat - slopes > 27°	= Summer range
Suitable habitat - north, west, east facing slopes (225°-135°) - areas with snowpack >25 cm	= Winter range
Suitable habitat - slopes < 27° - north-facing slopes (315° - 45°) - areas > 1 km from water - areas < 2 contiguous ha	= Lambing range
Suitable habitat - (areas w/ HV = 30 to 55% > 4.5 km) - (areas w/ HV < 30% > 100m)	= Movement zones

Table 3. Habitat criteria used for evaluation of suitable summer, winter and lambing ranges and movement corridors for bighorn sheep (Smith *et al.* 1991). Habitat requirements are shown in equation form.

The Biological Panel

An 18 person, interagency panel was convened on May 31, 1995 to interpret and evaluate the GIS results and its implications for management of bighorn sheep in the greater Bighorn Canyon National Recreation Area. The panel was also asked to address other criteria that the GIS results could not account for. The panel members were: Ann Blankenship, wildlife biologist from Bighorn National Forest, Vernon Bleich, senior wildlife biologist from the California Department of Fish and Game; Tom Easterly, wildlife biologist from the Wyoming Department of Game and Fish; John Emmerich, wildlife management coordinator from the Wyoming Department of Game and Fish; Charles Eustace, regional game manager from the Montana Department of Fish, Wildlife and Parks; Michelle Gudorf, GIS resource analyst from the National Park Service; Lynn Irby, professor of wildlife biology from Montana State University; David Jaynes, natural resource manager from the Bureau of Land Management; Bert Jellison, habitat biologist from the Wyoming Department of Game and Fish; Robert Kissell, Ph.D. student in ungulate studies from Montana State University; Jack Lindsey, GIS specialist from Bighorn Canyon National Recreation Area; Jay Parks, biologist from the Bureau of Land Management; Terry Peters, natural resource specialist from Bighorn Canyon National Recreation Area; Kim Reid resource assistant from the U.S. Forest Service; Francis Singer, senior research ecologist from the National Biological Service; Shawn Stewart, wildlife biologist from the Montana Department of Fish, Wildlife and Parks; Patricia Sweanor, wildlife biologist from the National Biological Service; and Tom Voss, rangeland specialist from the Bureau of Land Management.

Figure 3. The four focus areas for the bighorn sheep habitat assessment study of the greater Bighorn Canyon National Recreation Area.



RESULTS

GIS Analysis of Geophysical and Biological Parameters

Continuous expanses of escape terrain occur along major canyon drainages and ridgelines in the study area, including Bighorn Canyon, Crooked Creek, Devil Canyon, Black Tail Creek, Big Bull Elk Creek, Little Bull Elk Creek, Black Canyon Creek, East Pryor Mountain, and Little Mountain. The narrow expanse of ledges along the Bighorn Canyon, serves as the principle escape terrain for bighorn sheep in Bighorn Canyon National Recreation Area. However, more extensive escape terrain occurs in the canyons and ridges of the Pryor Mountains and the Bighorn Mountains. There was estimated to be 2215.0 km^2 of escape terrain and buffer zones in the study area (Table 4).

Unlike Bighorn Canyon, which occurs in relatively open vegetation zones, the escape terrain in the Pryor and Bighorn Mountains is limited by tree-cover. Many areas in or near escape terrain in both the Pryor and Bighorn Mountains are covered in Douglas Fir. Both coniferous forests and riparian zones were estimated to have visibility ratings less than 55% and, thus, would be unacceptable habitat for bighorn sheep (Johnson and Swift 1995). However, identifying the distribution and extent of these vegetation zones was hampered by the lack of fine scale vegetation maps. All other vegetation community types were considered open enough for bighorn sheep. Transects to evaluate the openness of the vegetation communities were run in juniper/mahogany shrublands, desert shrublands and sagebrush steppes. No transects were run in grassland areas and they were estimated to have visibility ratings greater than 80%. Horizontal visibility in juniper/mahogany shrublands was 60.5% (sd = 23.1, n = 50), in desert shrublands was 87.2% (sd = 17.0, n = 10) and in sagebrush steppe was 79.1% (sd = 19.0, n = 20). The mean value for horizontal visibility in juniper/curlleaf mahogany shrublands was only 5.5% greater than the minimum acceptable level (Johnson and Swift 1995). The high variability around the mean value indicates that, some stands of juniper/mahogany shrubland are not acceptable habitat for bighorn sheep. However, all juniper/curlleaf mahogany stands were included with estimates of suitable habitat since vegetation maps delineating stand density were not available. A total of 124.6 km^2 was removed from buffered escape terrain due to restricted horizontal visibility (Table 4).

Perennial water availability was adequate through most of the study area. However, some areas of buffered escape terrain were greater than 3.2 km from documented water sources, resulting in the removal of 249.6 km^2 from consideration as suitable bighorn sheep habitat (Table 4).

No natural landscape features in the study area were considered permanent barriers to bighorn sheep movements. Bighorn Canyon and Bighorn Lake present formidable obstacles, and yet, bighorn sheep reportedly dispersed from Devil Canyon to the western side of Bighorn Canyon (Coates and Schemnitz 1989). Bighorn sheep may be able to cross the lake during winter freeze-ups. During an ongoing 3-year study of bighorn sheep, utilizing radio-telemetry and aerial surveys (Irby *et al.* 1995), no movements of bighorn sheep from the western side of the canyon to the eastern side were documented.

Snow depth measurements on slopes near escape terrain were not available. Due to insufficient quantified data documenting snow depth, this parameter was not incorporated into the GIS analysis of suitable habitat. Winter surveys of snow depth on proposed winter ranges should be conducted.

GIS Analysis of Land Management Constraints

Human use areas, such as group campsites, visitor/information centers and scenic overlooks, affecting 1.7 km^2, were removed from estimates of suitable bighorn sheep habitat (Table 4), as delineated in the model.

Manmade barriers in the greater Bighorn Canyon National Recreation Area consist primarily of cattle fences and roads. New fences constructed in the recreation area incorporate modifications recommended by Helvie (1971) to allow for the passage of bighorn sheep. No impassable stretches of fenceline were noted in this analysis, however, all translocation sites should be inspected for fences that would hinder bighorn sheep movements, and such fences should be modified or removed. No roads or trails were considered barriers, but the 40.0 km^2 area they occupied was removed from estimates of suitable habitat (Table 4), in accordance with model parameters.

Domestic sheep allotments occur in the southeastern corner of the study area. These allotments affected 292.5 km^2 of otherwise suitable bighorn sheep habitat (Fig. 4).

Bighorn Sheep Habitat Requirements:	Effect on Land Area Available (km^2)	
	Land area removed due to habitat constraint	Land area remaining
Escape Terrain (ET) and Buffer (BT)	-1203.0 km^2	= 2215.0 km^2
Horizontal Visibility Constraint (HV)	- 124.6 km^2	= 2090.4 km^2
Water Source Constraint (WS)	-249.6 km^2	= 1840.8 km^2
Natural Barrier Constraint (NB)	-0 km^2	= 1840.8 km^2
Human-use Area Constraint (HU)	-1.7 km^2	= 1839.1 km^2
Manmade Barrier Constraint (MB)	-40.0 km^2	= 1799.1 km^2
Domestic Livestock Constraint (DL)	- 292.5 km^2	= 1506.6 km^2

Table 4. Quantifiable criteria used in the GIS for determination of land area suitable for bighorn sheep in the 3418 km^2 greater Bighorn Canyon National Recreation Area.

No.	Domestic sheep Allotment name	Domestic Sheep AUMs	Dates
13	Antelope Ridge	2400	7/1-9/10
7 & 8	Bear Creek/ Crystal Creek	2457	7/6-9/10
2	Beaver Creek	2273	7/6-9/5
5	Little Horn	2880	7/6-9/15
6	Pole Creek	2880	7/6-9/15
15	Wallrock-Hidden Tepee	3080	7/1-9/15
3	Whaley Creek	2815	6/26-9/15
40 & 41	Crooked Creek no. 1&2	currently cattle, may request sheep	

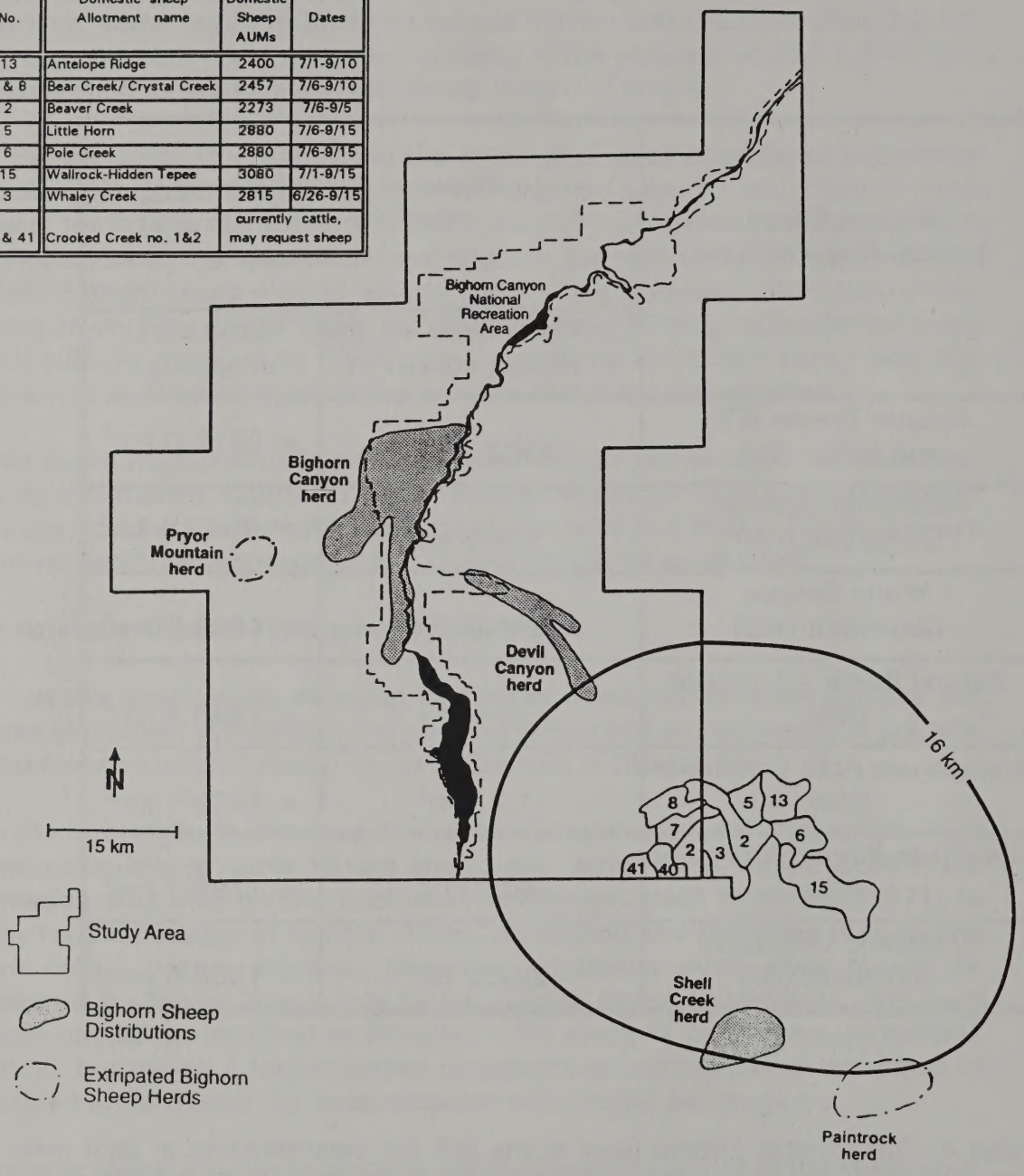


Figure 4. Domestic sheep grazing allotments in and around the greater Bighorn Canyon NRA study area.

Non GIS Factors

In a study of plant communities in Bighorn Canyon NRA, current annual growth (CAG) of grasses and forbs varied from 260 to 450 kg/ha and CAG of curlleaf mahogany, in 4 random plots, averaged 90 kg/ha, (J. Peterson, NREL, Colorado State Univ., Fort Collins, CO, unpubl. data). Coates and Schemnitz (1989) estimate that mahogany constitutes 46% of bighorn sheep diets, grass, 40% and forbs, 14%. Since the distribution of plant species in suitable bighorn sheep habitat was not determined, carrying capacity based on forage biomass production can only be roughly calculated. Thorne *et al.* (1979) estimated that one bighorn sheep requires 620 kg of forage per year. Assuming that 50% of the habitat is vegetated in curlleaf mahogany and grass/forb understories, having a combined CAG of 350 kg/ha, then, if bighorn sheep consume half of the available forage, 7.1 ha would provide the yearly forage biomass needs of one bighorn sheep. A minimum viable population would require 8.9 km^2 of suitable habitat for forage needs.

Cattle occur in the study area. Impacts that cattle have on bighorn sheep, such as forage competition, are not clearly understood (McCarty and Bailey 1994). It has been suggested that cattle should be restricted from bighorn sheep watering sites to limit possible transmission of disease (Jessup 1985). The presence of cattle has had less effect on bighorn sheep herd health than the presence of domestic sheep (Dodd and Brady 1986).

Mountain lion predation is a mortality factor in bighorn sheep herds in Bighorn Canyon National Recreation Area. Predation was determined to be the cause of death of two radio-collared bighorn sheep in Bighorn Canyon NRA (Irby *et al.* 1995).

MANAGEMENT IMPLICATIONS

The location and amount of bighorn sheep habitat was estimated and categorized as summer, winter and lambing ranges (Table 5, Figs. 5, 6, 7, 8).

	Focus Area 1	Focus Area 2 ^	Focus Area 3	Focus Area 4	Study Area	Required for MVP (Smith *et al.* 1991)
suitable habitat	736.1 km^2	939.9 km^2	42.2 km^2	80.9 km^2	1799.1 km^2	17 km^2
summer habitat	570.0 km^2	580.4 km^2	40.8 km^2	72.6 km^2	1263.8 km^2	9.7 km^2
winter habitat	306.6 km^2	274.9 km^2	17.6 km^2	27.8 km^2	626.9 km^2	6.5 km^2
lambing habitat	63.5 km^2	144.0 km^2	0.1 km^2	1.4 km^2	209.0 km^2	3.6 km^2
estimated no. current bighorn	158	40+	0	0		
carrying capacity based on most limiting seasonal range	>125	>125	0	35*		
carrying capacity based on 1 AUM/12.4 ha	>125	>125	N/A	>125		

^ Currently 292.5 km^2 of bighorn sheep habitat in Focus Area 2 is affected by domestic sheep
* Based on a 2:1 ewe:ram ratio
+ 1985 population estimate

Table 5. Estimates of bighorn sheep habitat in the greater Bighorn Canyon NRA area, based on habitat parameters defined in Smith *et al.* (1991). This model run does not take into account the effects of domestic sheep on the availability of bighorn sheep habitat. Focus Area 2 will have reduced amounts of suitable habitat due to the presence of domestic sheep (Fig. 4). Note that seasonal ranges may overlap and, therefore, summations of seasonal range areas may exceed total suitable habitat.

Figure 5. Suitable bighorn sheep habitat in the greater Bighorn Canyon NRA area.

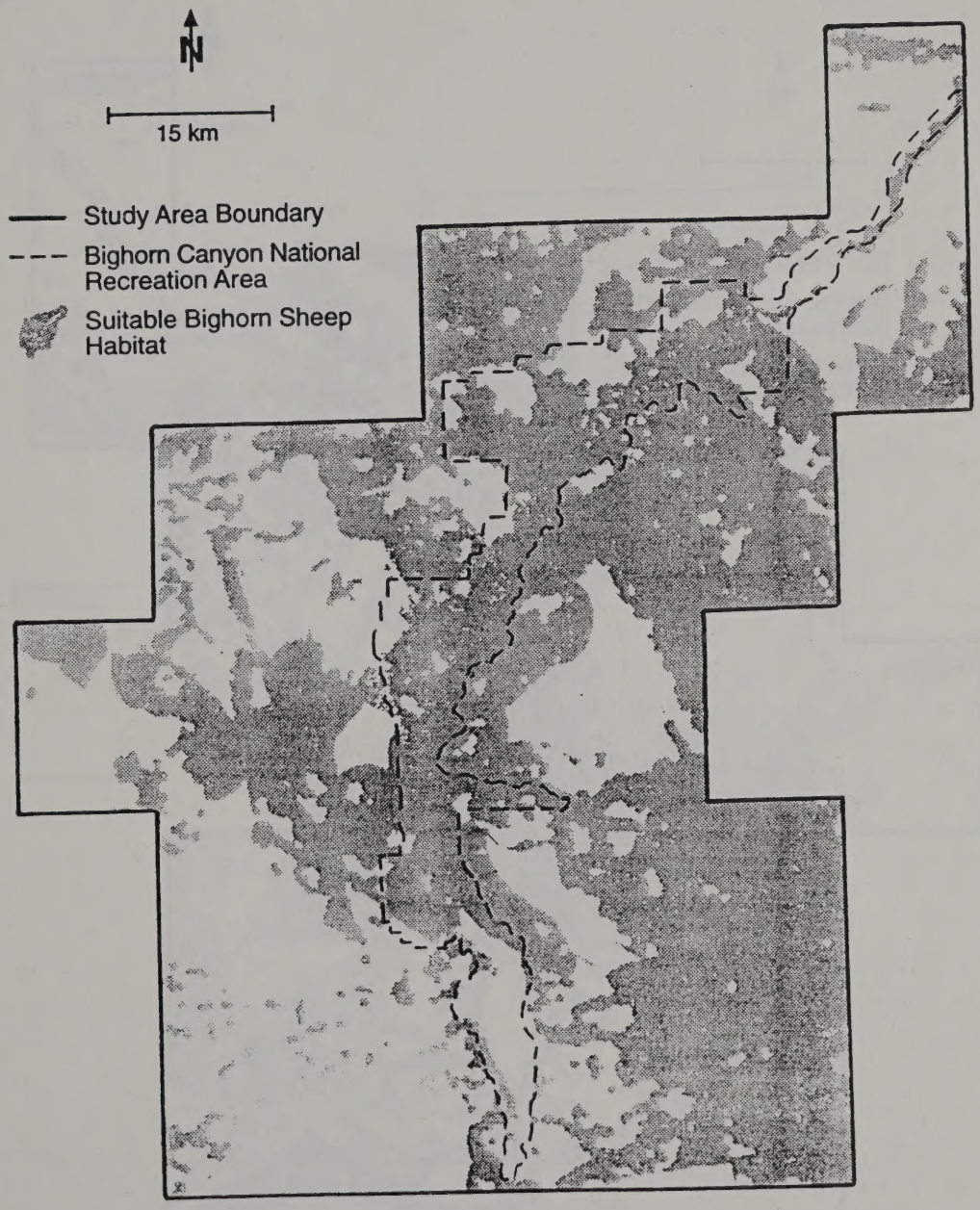


Figure 6. Suitable summer habitat for bighorn sheep in the greater Bighorn Canyon NRA area. Note that ewes with lambs would also be expected to use lambing habitat (Fig. 8) during summer.

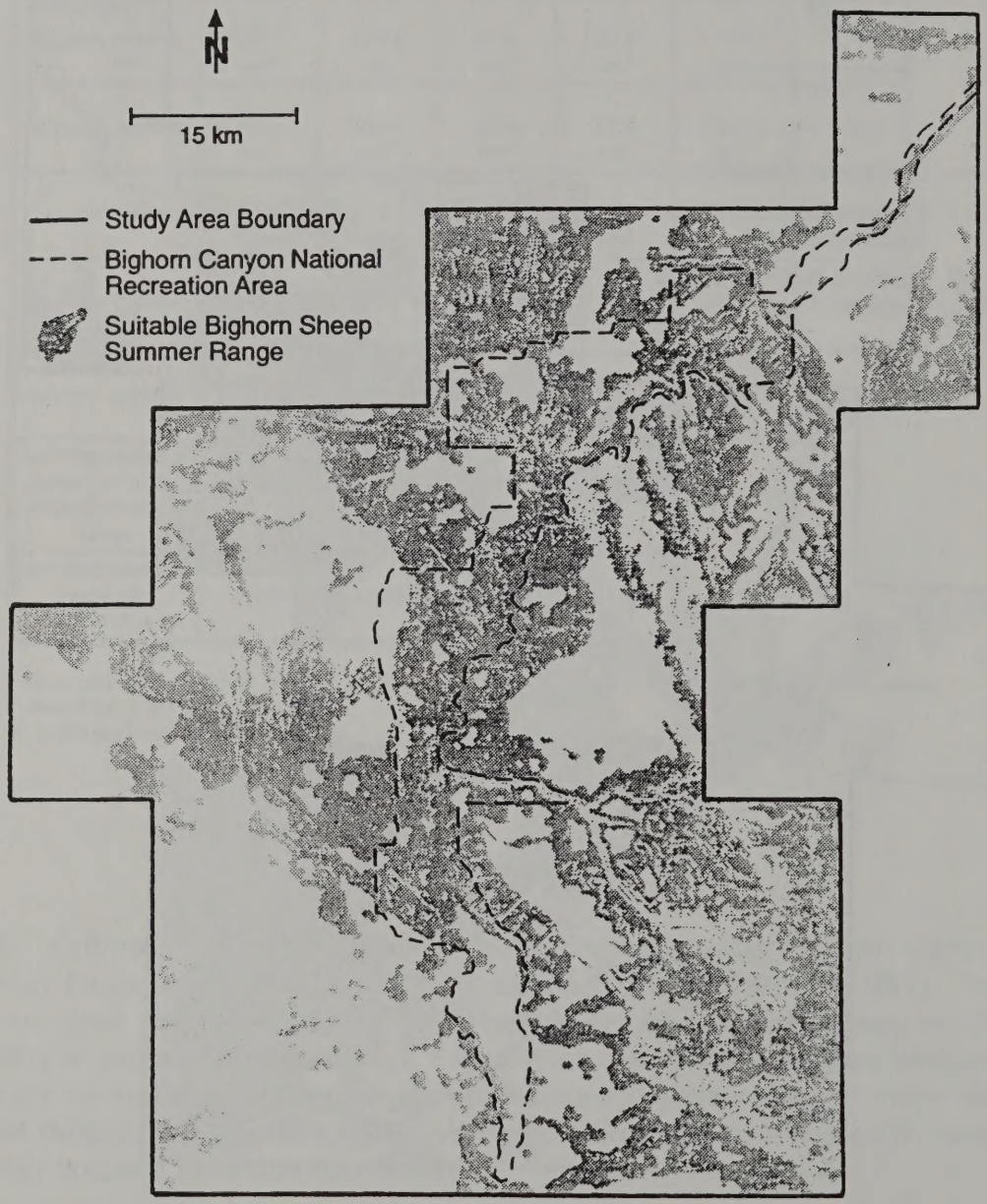


Figure 7. Suitable winter habitat for bighorn sheep in the greater Bighorn Canyon NRA area. Snow depth was not evaluated.

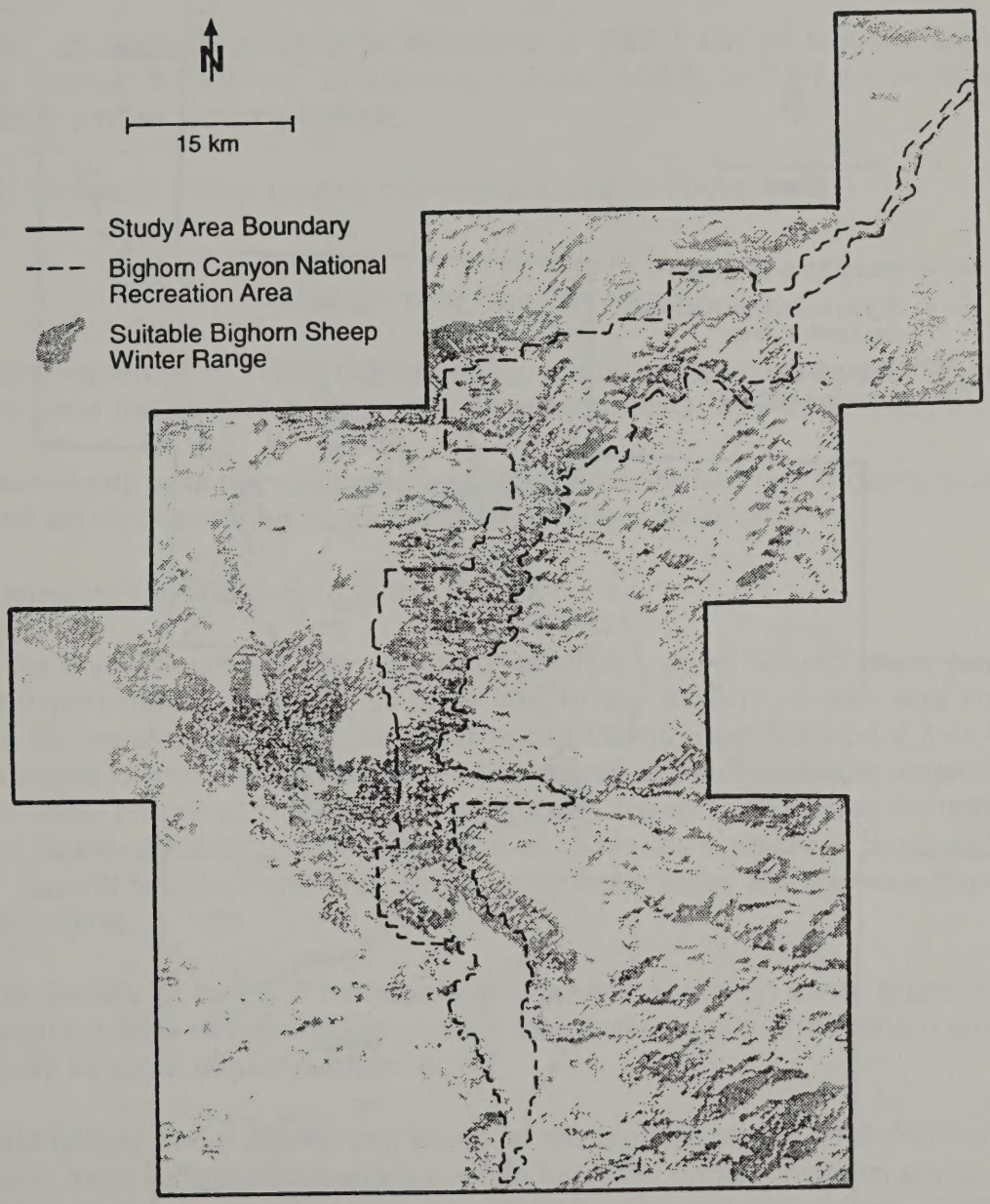
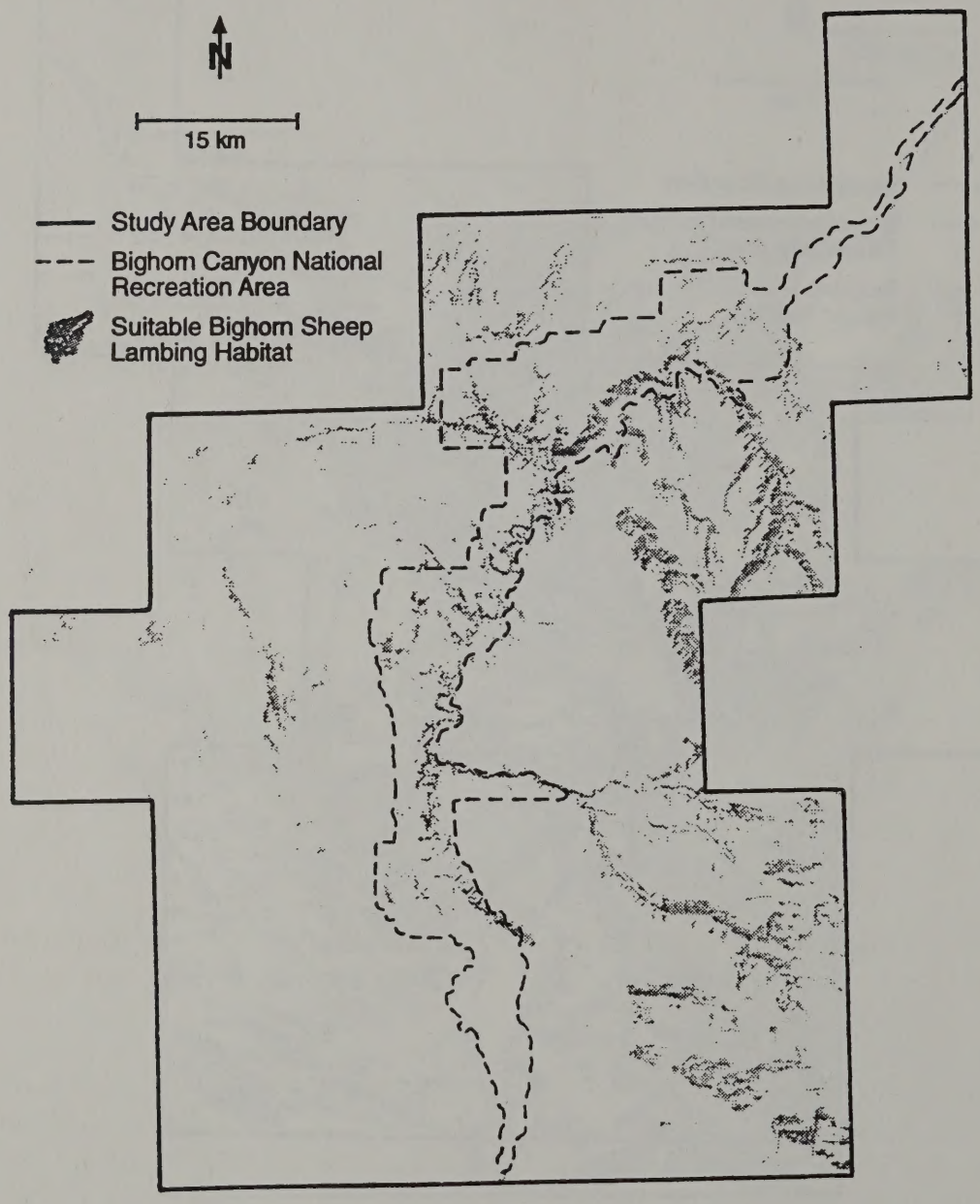


Figure 8. Suitable lambing habitat for bighorn sheep in the greater Bighorn Canyon NRA area.



Focus Area 1: West side of Bighorn Canyon and Pryor Mountains (Fig. 3)

Positive Attributes

1. The GIS analysis resulted in estimates of 736.1 km^2 of suitable bighorn sheep habitat, 570.0 km^2 of summer habitat, 306.6 km^2 of winter habitat and 63.5 km^2 of lambing habitat.

2. No domestic sheep grazing allotments occur in Focus Area 1.

Management Considerations

1. A population of 117-199 bighorn sheep occupy the western rim of Bighorn Canyon and the eastern edge of the Pryor Mountains (Irby *et al.* 1995).

2. Snow depth was not evaluated and snow pack in the Pryor Mountains may exceed 25 cm, rendering some areas unsuitable winter range.

3. Barb-wire fencing occurs in the area.

4. In the Pryor Mountains many areas of otherwise good bighorn sheep terrain are not presently considered suitable due to the density of tree and shrub cover. Areas of dense cover, and thus poor visibility, may have been included in estimates of suitable habitat due to the coarse scale of available vegetation maps. Any proposed translocation of bighorn sheep to the Pryor Mountains should be preceded by ground evaluation of horizontal visibility at the specified site. Natural or prescribed fires could create open areas and increase bighorn sheep habitat.

5. The density of curl-leaf mahogany and juniper stands in some areas along the western edge of Bighorn Canyon are marginally suitable for bighorn sheep, and may become denser with time.

6. Wild horses occur throughout much of the bighorn sheep herd distribution in Focus Area 1. Potential dietary overlap between horses, bighorn sheep and mule deer are being studied (Irby *et al.* 1995). The overlap of bighorn sheep and horse range may have both positive and negative effects (see Discussion).

7. Cattle grazing occurs in Focus Area 1. Jessup (1985) suggested that cattle should be restricted from bighorn sheep watering sites to limit possible disease transmission.

Potential for Translocating Bighorn Sheep into Focus Area 1

The biological panel advised that bighorn sheep should not be translocated into Focus Area 1 because the present population has increased in recent years and may be expanding its range. Natural dispersal, occurring in this population, would provide a good case study of bighorn sheep population movements and dynamics. Continued monitoring of bighorn sheep along Bighorn Canyon and Crooked Creek should be pursued to add to the data base already established by Irby *et al.* (1995), and to provide a longer term study of natural shifts and expansions in bighorn sheep distributions.

Focus Area 2: East side of Bighorn Canyon, Little Mountain, Devil Canyon (Fig. 3)

Positive Attributes

1. The GIS analysis resulted in estimates of 939.9 km^2 of suitable bighorn sheep habitat, 580.4 km^2 of summer habitat, 274.9 km^2 of winter habitat and 144.0 km^2 of lambing habitat.

Management Considerations

1. Domestic sheep grazing allotments occur in the southeastern corner of the study area, affecting 292.9 km^2 of otherwise suitable bighorn sheep habitat (based on a 16 km buffer around domestic sheep grazing). Bighorn sheep occurring in this area would be at risk of contracting disease from domestic sheep (Fig. 4).

2. Devil Canyon has not been surveyed for bighorn sheep during the last 10 years. A small band, originating from a translocation in 1973, is thought to still occupy the canyon along Porcupine Creek (Easterly, pers. comm.). In

1985 Vern Stelter, Wyoming Game and Fish Department, estimated that the population consisted of at least 40 bighorn sheep. The status and distribution of this herd should be documented prior to further translocations in this area.

3. Lack of widespread distributions of curlleaf mahogany in the southern part of Focus Area 2 was discussed as a possible limitation on the extent and quality of bighorn sheep habitat (see Discussion).

4. Barb-wire fences occur in Focus Area 2.

5. Cattle grazing occurs in Focus Area 2. Jessup (1985) suggested that cattle should be restricted from bighorn sheep watering sites to limit possible disease transmission.

6. Perennial water sources may be limited in Little Mountain.

7. Native elk (*Cervus elaphus*) populations occur in the northern portion of Focus Area 2.

Potential for Translocating Bighorn Sheep into Focus Area 2

Due primarily to the presence of domestic sheep, and secondarily to hypothesized concerns regarding the nutritional quality of the vegetation due to the lack of curlleaf mahogany, the panel recommended against any translocation into the southeastern corner of Focus Area 2. Additionally it was felt that the status of the bighorn sheep herd in Devil Canyon should be determined prior to any further supplemental translocations there.

In keeping with objectives of establishing a metapopulation structure (Bleich *et al.* 1990), the panel felt the most desirable location for a translocations would be in the northern half of Focus Area 2. The eastern rim of Bighorn Canyon contains suitable bighorn sheep habitat, comparable to that found on the western side now occupied by the Bighorn Canyon herd. Since this area is under the jurisdiction of the Crow Indian Nation, the panel recommended that cooperative agreements between the Crow Indian Reservation and other agencies involved in translocations be implemented prior to initiation of translocation efforts.

Focus Area 3: South and southeast of the Pryor Mountains (Fig. 3)

Potential for Translocations of Bighorn Sheep into Focus Area 3

The GIS analysis resulted in estimates of 42.2 km^2 of suitable bighorn sheep habitat, 40.8 km^2 of summer habitat, 17.6 km^2 of winter habitat and 0.1 km^2 of lambing habitat. The panel declined to consider Focus Area 3 for translocations of bighorn sheep due to the limited amounts of suitable habitat in the area.

Focus Area 4: Northeastern Bighorn Canyon NRA and adjacent lands (Fig. 3)

Positive Attributes

1. The GIS analysis resulted in estimates of 80.9 km^2 of suitable bighorn sheep habitat, 72.6 km^2 of summer habitat and 27.8 km^2 of winter habitat.

2. The suitable bighorn sheep habitat in the focus area is presently unoccupied by resident bighorn sheep.

3. The suitable habitat identified in this study may be contiguous with bighorn sheep outside the study area.

4. Domestic sheep are not grazed in Focus Area 4.

Management Considerations

1. Only 1.4 km^2 of lambing habitat was identified in Focus Area 4. This restricted amount of lambing habitat would be expected to support only 35 bighorn sheep according to the habitat model (Smith *et al.* 1991).

2. Cooperation between wildlife management agencies and the Crow Indian Nation is essential for effective bighorn sheep translocation programs, since Focus Area 4 occurs on the Crow Indian Reservation. Crow Indian Nation involvement should be required before further considering the translocation of bighorn sheep into Focus Area 4.

3. The northwestern ridges of the Bighorn Mountains, i.e., Big Bull Elk Ridge, Little Bull Elk Ridge, Little Finger Ridge, etc., have variable tree cover. Vegetation maps were too coarsely scaled to adequately delineate areas with plant cover too dense for bighorn sheep. If the area in Focus Area 4, south of the Bighorn River is considered for bighorn sheep translocations, biologists should survey the ridges to evaluate if vegetation cover is too dense, and then ground truth specific sites to insure habitat requirements are met.

4. Road access to translocation sites may be limited.

5. Cattle grazing occurs in Focus Area 4. Jessup (1985) suggested that cattle should be restricted from bighorn sheep watering sites to limit possible disease transmission.

6. Areas to the north of the study area need to be evaluated to identify areas of suitable bighorn sheep habitat contiguous with Focus Area 4.

Potential for Translocating Bighorn Sheep into Focus Area 4

Due to the limited amounts of lambing habitat identified in this analysis, no translocations of bighorn sheep should occur in Focus Area 4 unless adjacent areas are shown to contain additional lambing habitat. The biological panel further advised that bighorn sheep should not be translocated into Focus Area 4 unless management agreements are established between the Crow Indian Nation, Bighorn Canyon National Recreation Area and the Montana Department of Fish, Wildlife and Parks. After addressing these issues, Focus Area 4 with adjoining areas, could provide adequate habitat for translocated bighorn sheep.

Suggested Monitoring and Management

The Biological Panel prioritized management actions by suggesting two stages of action. The first stage is monitoring. The second stage involves bighorn sheep translocations and habitat management.

Stage 1: Monitoring (4 - 5 years)

1. Bighorn sheep movements and population dynamics in Bighorn Canyon National Recreation Area should continue to be monitored using radio-telemetry. There is an opportunity to establish long-term population dynamics data, by building on the work of Coates and Schemnitz (1988) and Irby *et al.* (1995), and to document dispersal, range expansion and development of migration patterns in a re-introduced population.

2. The bighorn sheep herd in Devil Canyon should be aerially surveyed to determine herd distribution, population size and recruitment rates.

Stage 2: Translocations and Habitat Management

Translocations

1. Bighorn sheep should be translocated to the eastern side of Bighorn Canyon if bighorn sheep have not expanded their range to this area. Procedures to obtain source stock should begin immediately, since the process may take 4 to 5 years.

2. Reintroductions of large numbers of bighorn should correlate with a high incidence of reintroduction success by reducing the effects of chance events of individual mortality (Griffith *et al.* 1989). However, limited numbers of source stock and economic concerns limit the number of bighorn sheep available for translocation. Symonds and Singer (unpubl. data) found that translocation success was improved when there were 25-30 founders per translocation. To reduce the effect of catastrophic events, maximize genetic heterozygosity, and provide dispersal stock should some herds die off, it may be beneficial if translocated herds are geographically separated into subpopulations that are close enough to allow for limited inter-breeding.

3. Translocations may either occur simultaneously or in stages. Supplemental translocations should be screened for diseases, since each new translocation may introduce diseases.

Habitat Management

1. The domestic sheep grazing allotments in the southeastern corner of Focus Area 2 should be retired or converted to cattle when opportunities arise. The domestic sheep allotments are a source of disease concerns for the Devil Canyon and Shell Creek bighorn sheep herds.

2. Controlled burns could be considered a management option in zones of Utah juniper/curlleaf mahogany, near escape terrain, to increase the openness of the habitat for bighorn sheep. However, the ability of Utah juniper/curlleaf mahogany shrublands to carry a fire and result in improve forage production is questionable (Irby and Kissell, pers. comm.). If burns are conducted, changes in forage production and bighorn sheep range use should be closely monitored to evaluate this management option. Controlled burns in the Pryor Mountains could increase bighorn sheep habitat that is limited and disjunct due to the succession of coniferous forest growth.

3. Evaluate barb-wire fencing in the area to determine if bighorn sheep could move through or around them while remaining within areas of suitable habitat. Fences should be modified, new fences should be built to meet standards that allow for bighorn movements (Helvie 1971, BLM 1989), and abandoned fences should be removed.

4. Non-constant factors must be periodically evaluated to determine the continued suitability of bighorn sheep ranges. The following are not static, and changes should alert managers to assess the need for management: physical barriers, such as construction of facilities, roads and fences; disturbance, such as increased human visitation and habitat manipulations; disease; domestic sheep within 16 km of bighorn sheep; succession to denser shrublands or forests; and fires that open heavily-vegetated areas.

Suggested Release-Site Evaluation

This habitat assessment, based on the GIS analysis, enables an overview of potential bighorn sheep habitat in study areas that are several thousand square kilometers in extent. When potential release sites, encompassing a few square kilometers, are identified through this broad spectrum assessment, it is prudent to recheck or ground-truth local habitat variables.

1.Ground-truth the summer range near the release site:

a.Verify the presence of escape terrain (slopes >27°, < 85°).
b.Verify the presence of water sources within 3.2 km of suitable habitat.
c.Verify that mean horizontal visibility is > 55%.
d.Verify that natural and manmade barriers, and human-use areas do not preclude movements of bighorn sheep.
e.Verify that free ranging domestic sheep do not occur within 16 km of suitable habitat.
f. Verify that forage production is > 620 kg/bighorn/yr. (Thorne *et al.* 1979).
g.Verify that high concentrations of other ungulates do not occur in the suitable habitat.
h.Monitor predator abundance.

2.Ground-truth the winter range near the release site:

a.Verify the presence of contiguous, south-facing (27°-85°) slopes with snow pack < 25 cm.
b.Repeat b. through h. listed under item 1.

3.Ground-truth the lambing range near the release site:

a.Verify the presence of contiguous (>2 ha) slopes > 27°
b.Verify the presence of water sources within 1 km of slopes > 27°.
c.Verify that slopes are not north-facing.
d.Repeat c. through h. listed under item 1.

Source Stock Recommendations

1. Select healthy source populations of bighorn sheep with high recruitment.
2. Select indigenous source populations when possible, since they may have higher genetic heterozygosity than do reintroduced populations.
3. If the source herd must be a reintroduced population, choose populations that came from native source herds, i.e., select secondary dilutions before tertiary or greater dilutions.
4. Select populations from similar geographic terrain, in close proximity to the study area. Bighorn sheep from the South Fork of the Shoshone River, Wyoming may be available for translocation into the study area (Easterly pers comm.)
5. Select multiple populations for source stock. Translocations of mixed stock may be more successful than translocations from one source herd.

DISCUSSION

The steep, rugged terrain in Bighorn Canyon and its canyon tributaries, such as Devil Canyon and Crooked Creek, constitute a critical feature of bighorn sheep range. Steep, rugged areas, termed escape terrain (Smith *et al.* 1991) provide a refuge where bighorn sheep can evade predators and other dangers or disturbances (Honess and Frost 1942, Cooperrider 1969, McCollough 1982, Holl and Bleich 1983). Escape terrain is a primary determinant of bighorn sheep habitat, and identifying its distribution enables a quick overview to determine the potential of a region to support bighorn sheep populations. Some sections of the study area were unsuitable habitat for bighorn sheep due to the lack of escape terrain, such as the area south of the Pryor Mountains, as well as Garvin Basin to the east of Bighorn Canyon.

The openness of plant communities, termed horizontal visibility, is another fundamental determinant of bighorn sheep habitat quality. Bordering the escape terrain of Bighorn Canyon are areas of shrubland with understory grasses where bighorn sheep forage. However, along the rim of Bighorn Canyon many stands of curlleaf mahogany, an important forage species for bighorn sheep in this area (Coates and Schemnitz 1989), are only marginally open enough for bighorn sheep. Natural succession of these shrublands to dense stands will make them increasingly less suitable for bighorn sheep. Bighorn sheep avoid, and have reduced feeding efficiency in plant communities that obscure their view of potential dangers (Buechner 1960, Geist, 1971, Risenhoover 1981, Wakelyn 1984). Bighorn sheep utilizing marginal, overgrown stands of vegetation, would be expected to have decreased feeding efficiency, due to increased needs for vigilance, and increased predator mortality rates, compared with bighorn sheep in open ares near escape terrain (Risenhoover and Bailey 1980). Coates and Schemnitz (1989) suggested that the presence of wild horses in Bighorn Canyon NRA enables rams to utilize shrublands that are thicker and farther from escape terrain than bighorn sheep would normally use. They proposed that bighorn sheep take advantage of the horses' abilities to sense and signal danger in the shrubland areas. However, during more recent studies in Bighorn Canyon NRA, this behavior has not been observed (Kissell pers. comm.)

The Pryor Mountains contain potential escape terrain for bighorn sheep. Crooked Creek in the eastern side of the mountains is already occupied by bighorn sheep. However, large expanses of the Pryor Mountains are covered

in trees and dense shrubs, rendering them generally unsuitable for bighorn sheep, although rams occasionally utilize such areas in fall and winter. Sections of canyons with adequate horizontal visibility in the Pryor Mountains, such as Crooked Creek, are isolated from other open canyons scattered through the mountains. The northwestern ridges of the Bighorn Mountains, from Big Bull Mountain to Black Canyon also contain forested areas that reduce and disrupt the continuity of potential bighorn sheep habitat. Detailed vegetation maps delineating vegetation type and stand density were not available for the Pryor Mountains, and the Bighorn Mountains in the Crow Indian Reservation, therefore, open areas may be overestimated resulting in overestimates of suitable habitat. Limited horizontal visibility is a major constraint on potential bighorn sheep habitat, but the potential for fire in the area is high (Irby pers comm.) and burns could significantly increase available habitat.

Devil Canyon contains suitable bighorn sheep habitat, and it is presently occupied by a small herd. However, domestic sheep grazing negatively affects the area south of Devil Canyon. In addition, the low elevation rangelands may not provide the nutritional needs of bighorn sheep (Herbert 1973). The presence of deciduous shrubs, such as curlleaf mahogany, enable bighorn sheep to subsist on low elevation ranges where they do not have the possibility to migrate altitudinally along plant phenological, and species gradients (Rominger *et al.* 1988, Cook 1990). Curlleaf mahogany is not widely distributed in the study area south of Devil Canyon. The effect of curlleaf mountain mahogany distributions on bighorn sheep foraging behavior is not fully understood. If bighorn sheep are translocated to the southern part of Focus Area 2, forage studies could increase our understanding of bighorn sheep nutritional needs on low elevational ranges.

There is suitable bighorn along the western and eastern rims of Bighorn Canyon, in small canyons in the Pryor Mountains and Bighorn Mountains, and in Devil Canyon with its peripheral canyons. These areas, except the eastern rim of Bighorn Canyon and the small ridges of the Bighorn Mountains, are either presently occupied by bighorn sheep or occur near an expanding herd of bighorn sheep. The biological panel considered the eastern rim of Bighorn Canyon to be the area of highest priority for bighorn sheep translocations. The biological panel recommended continued monitoring of the Bighorn Canyon herd to increase understanding of dispersal, range expansion and establishment of seasonal migration patterns.

CONCLUSIONS

1. The western rim of Bighorn Canyon should be considered occupied, by bighorn sheep with no present need for translocations, since the population has continued to increase in numbers and expand its range in the last decade (Coates and Schemnitz 1989, Irby *et al.* 1995).

2. Population and habitat monitoring programs should be continued while plans to procure bighorn sheep for translocation are initiated

   a. Continued monitoring of the Bighorn Canyon herd would advance understanding of bighorn sheep dispersal, range expansion and development of seasonal migration patterns.

   b. Little is known about the current status of the Devil Canyon herd. Monitoring this herd, and identifying population numbers and distribution, would enable better informed decisions regarding potential translocations on the eastern rim of Bighorn Canyon.

   c. The eastern rim of Bighorn Canyon, north of Devil Canyon, contains similar, suitable bighorn sheep habitat to the western rim, and is apparently unoccupied by bighorn sheep. This was the biological panel's preferred site for a translocation of bighorn sheep into the study area. Bighorn sheep in this area would have the potential to become part of a metapopulation that included the Bighorn Canyon, the Devil Canyon, and possibly the Shell Creek herds.

4. Although curlleaf mahogany stands are preferred foraging areas for bighorn sheep (Coates and Schemnitz 1989), some areas of mahogany shrubland in the study area currently are too dense, with inadequate levels of horizontal visibility, for bighorn sheep (Johnson and Swift 1995).

5. Prescribed burns should be considered to increase the openness of marginal shrubland areas and increase forage production. Burns should be evaluated to determine their effect on forage production and use by bighorn sheep.

6. Domestic sheep grazing allotments near Bald Mountain may increase the possibility of disease transmission to the Devil Canyon and Shell Creek herds. As opportunities arise, through changes in livestock operators or requests for changes in kinds of livestock, attempts should be made to convert sheep allotments to cattle. However, concerns about grazing impacts in the riparian zones of those allotments may limit that option (Easterly, pers. comm.)

7. Although the biological panel, at present, did not suggest translocating bighorn sheep into the Pryor Mountains, the Montana Department of Fish, Wildlife and Parks has previously identified the area as a potential translocation site. Areas of suitable habitat in the Pryor Mountains are small and disjunct due to dense forest stands and shrublands. A detailed and current vegetation map of the Pryor Mountains was unavailable for this analysis, therefore, potential translocation sites should be ground-truthed for adequate horizontal visibility prior to any translocation effort in the Pryor Mountains. Fire could increase the amount of bighorn sheep habitat in the area.

8. Translocations to the southern part of Focus Area 2, south of the Devil Canyon herd have the potential to interconnect herds of bighorn sheep but could also increase domestic sheep and bighorn sheep encounters. A translocation of bighorn sheep near domestic sheep may cause increased threats to distant, but interconnected bighorn sheep herds.

LITERATURE CITED

Bailey, J. A. 1990. Management of Rocky Mountain bighorn sheep herds in Colorado. Colorado Division of Wildlife. Species Report 66. 24 pp.

Bear, G. D. and G. W. Jones. 1973. History and distribution of bighorn sheep in Colorado. Colorado Division of Wildlife. Species Report 45. 12 pp.

Berger, J. 1990. Persistence of different sized populations: an empirical assessment of rapid extinctions in bighorn sheep. Conservation Biology. 4:91-98.

Bighorn Canyon NRA. 1985. Natural resources project statement. in files. Bighorn Canyon National Recreation Area, Lowell, Wyoming.

Bleich, V.C., Wehausen, J.D., and S.A. Holl. 1990. Desert-dwelling mountain sheep: Conservation implications of a naturally fragmented distribution. Conservation Biology 4:383-390.

BLM, CDOW. 1989. Colorado desert bighorn sheep management plan. BLM, CDOW, Grand Junction, Colorado.

Buechner, H. K. 1960. The bighorn sheep in the United States, its past, present and future. Wildlife Monographs 4. 174 pp.

Burrough, P. A. 1986. Principles of geographical information systems for land resources assessment. Clarendon Press. Oxford. 193 pp.

Capurro, W. N. 1988. Entire California bighorn herd dies in the Warner Mountains. p.65 in: Wild Sheep, Foundation for North American Wild Sheep. summer issue. Sigler Printing and Publishing. Ames, Iowa.

Coates, Kevin P., and Sanford D. Schemnitz. 1988. Habitat utilization, interspecific interactions and status of a recolonized population of bighorn sheep at a wild horse range. Project completion report to NPS and BLM. Mexico State Univ. Las Cruces, New Mexico. 71 pp.

Coates, Kevin P., and Sanford D. Schemnitz. 1989. The bighorn sheep of Bighorn Canyon National Recreation Area and the Pryor Mountain Wild Horse Range: Ecological relationships and management recommendations. Project completion report to NPS and BLM. New Mexico State Univ. Las Cruces, New Mexico. 47 pp.

Coggins, V. L. 1988. The Lostine Rocky Mountain bighorn sheep die-off and domestic sheep. Bienn. Symp. North. Wild Sheep and Goat Council. 6:57-64.

Cook J. G. 1990. Habitat, nutrition and population ecology of two transplanted bighorn sheep populations in south-central Wyoming. Ph.D. Dissertation, Univ. of Wyoming, Laramie. 310 pp.

Cooperrider, A. Y. 1969. Competition for food between mule deer and bighorn sheep on Rock Creek winter range, Montana. M.S. Thesis, Montana State Univ., Bozeman. 92 pp.

Dodd, N. L. and W. W. Brady. 1986. Cattle grazing influences on vegetation of a sympatric desert bighron range in Arizona. Desert Bighorn Council Trans. 32:1-6.

Ferrier, G. J., and W. G. Bradley. 1970. Bighorn habitat evaluation in the Highland Range in southern Nevada. Desert Bighorn Sheep Council Trans. 14:69-93.

Geist, V. 1971. Mountain sheep, a study in behavior and evolution. Univ. Chicago Press, Chicago. 383 pp.

Gibson, C.H. 1984. Delineation of bighorn sheep range and habitat capability; monitoring and evaluation. Bighorn National Forest range and wildlife program review. Bighorn National Forest.

Goodson, N. J. 1982. Effects of domestic sheep grazing on bighorn sheep populations. Bienn. Symp. North. Wild Sheep and Goat Council 3: 287-313.

Griffith, B., J. M. Scott, J. W. Carpenter and C. Reed. 1989. Translocation as a species conservation tool: status and strategy. Science 245:477-480.

Herbert, D.M. 1973. Altitudinal migration as a factor in the nutrition of bighorn sheep. Ph D. Dissertation., Univ. British Columbia, Vancouver. 356 pp.

Helvie, J. B. 1971. Bighorns and fences. Desert Bighorn Council Trans. 26:47-49.

Holl, S. A. and V. C. Bleich. 1983. San Gabriel mountain sheep and biological and management considerations. San Bernardino National Forest, San Bernardino, CA. 135 pp.

Honess, R. F. and N. M. Frost. 1942. A Wyoming bighorn sheep study. Wyoming Game and Fish Comm. Bull. No. 1. 127 pp.

Irby, Lynn, R., R. J. Mackie and Robert E. Kissell. 1994. Competitive interactions between bighorn sheep, wild horses, and mule deer in Bighorn Canyon National Recreation Area and Pryor Mountain Wild Horse Range. Second Annual Report. Dept. of Biology, Montana State Univ., Bozeman.

Irby, Lynn, R., R. J. Mackie and Robert E. Kissell. 1995. Competitive interactions between bighorn sheep, wild horses, and mule deer in Bighorn Canyon National Recreation Area and Pryor Mountain Wild Horse Range. Third Annual Report. Dept. of Biology, Montana State Univ., Bozeman.

Jessup, D. A. 1981. Pneumonia in bighorn sheep:effects on populations. Cal-Neva Wildlife Society Trans., pp. 72-78.

Jessup, D. A. 1985. Diseases of domestic livestock which threaten bighorn sheep populations. Desert Bighorn Council Trans.. 29:29-33.

Johnson, R. L. 1983. Mountain goats and mountain sheep of Washington. Washington Department of Game, Biological Bulletin No. 18. 196 pp.

Johnson, T. and M. Swift. 1995. A test of a Rocky Mountain bighorn sheep habitat evaluation procedure. Rocky Mountain National Park report. Rocky Mountain National Park, CO.

Knight, D. H., G. P. Jones, Y. Akashi and R. W. Myers. 1987. Vegetation ecology in the Bighorn Canyon National Recreation Area. final report. Univ. of Wyoming National Park Service Research Center. 114 pp.

McCann, L. J. 1956. Ecology of the mountain sheep. American Midland Naturalist 56:297-324.

McCarty, C. W. and J. A. Bailey, 1994. Habitat requirements of desert bighorn sheep. Colorado Division of Wildlife. Special report no. 69. 27 pp.

McCollough, S.A. 1982. Impact of cattle grazing on bighorn sheep, Trickle Mountain, Colorado. M.S. Thesis, Colorado State Univ., Fort Collins. 119pp.

McQuivey, R. P. 1978. The desert bighorn sheep of Nevada. Dept. Fish and Game Biology Bull. No. 6, Reno, NV. 81 pp.

Risenhoover, K. L. 1981. Winter ecology and behavior of bighorn sheep, Waterton Canyon, Colorado State Univ., Fort Collins. 107 pp.

Risenhoover, K.L. and J.A. Bailey. 1980. Visibility: An important factor for an indigenous, low-elevation bighorn herd in Colorado. North. Wild Sheep and Goat Council. 2:18-28.

Rominger, E.M., A. R. Dale and J. A. Bailey. 1988. Shrubs in the summer diet of bighorn sheep. J. Wildl. Manage. 52:47-50.

Rowland, M. M. and J. L. Schmidt. 1981. Transplanting desert bighorn sheep - a review. Desert Bighorn Council Trans. pp 25-28.

Sands, A. R. 1976. Evaluation of potential California bighorn sheep habitat, Jackson Mountains, Nevada. M.S. Thesis, Humboldt State Univ., Arcata, CA. 104 pp.

Sloan, W. B. 1995. A herd history of the bighorn sheep of Bighorn Canyon National Recreation Area. unpubl. report. Bighorn Canyon National Recreation Area, Lovell, WY. 17 pp.

Smith, T. S. and J. T. Flinders. 1991. The bighorn sheep of Bear Mountain: ecological investigations and management recommendations. final report. Utah Division of Wildlife Resources. 394 pp.

Smith, T. S., J. T. Flinders and D. W. Olsen. 1988. Status and distribution of Rocky Mountain bighorn sheep in Utah. Bienn. Symp. North American Sheep

and Goat Council 6:5-12.

Smith, T. S., J. T. Flinders and D. S. Winn. 1991. A habitat evaluation procedure for Rocky Mountain bighorn sheep in the Inter-mountain West. Great Basin Naturalist 51: 205-225.

Symonds, K. and F. J. Singer. in prep. Persistence of translocated populations of bighorn sheep in the Rocky Mountains.

Thorne, E.T., G. Bulter, T. Varcalli, K. Becker and S. Hayden-Wing. 1979. The status, mortality and response to management of the bighorn sheep of Whiskey Mountain, Wyoming. Wyoming Game & Fish Dept. Tech Report 7. 213 pp.

Tilton, M. E. and E. E. Willard. 1982. Winter habitat selection by mountain sheep. J. Wildl. Manage. 46:359-366.

USDI. 1988. National Park Service. Management Policies. 129 pp.

Van Dyke, W. A., A. Sands, J. Yoakum, A. Polentz, and J. Blaisdell. 1983. Wildlife habitat in managed rangelands-the Great Basin of southeastern Oregon: bighorn sheep. USDA Forest Service General Technical Report. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. 37 pp.

Wakelyn, L. A. 1984. Analysis and comparison of existing and historic bighorn sheep ranges in Colorado. M.S. Thesis. Colorado State Univ. Fort Collins. 111 pp.

Wakelyn, L. A. 1987. Changing habitat conditions on bighorn sheep ranges in Colorado. J. Wildl. Manage. 51:904-912.

Wilson, L. O., J. Blaisdell, G. Welsh, R. Weaver, R. Brigham, W. Kelly, J. Yoakum, M. Hinks, J. Turner, and J. DeForge. 1980. Desert bighorn habitat requirements and management recommendations. Desert Bighorn Council Trans. 24:1-7.

Wishart, W.1978. Bighorn sheep. pp. 161-171, In: J.L. Schmidt and D.L. Gilbert, eds. Big Game of North America. Stackpole Books, PA. 494 pp.